We thank the **reviewer #1** for his/her comments which should lead to a clearer manuscript, notably regarding the simulation set-up, the understanding of processes leading to changes on polar night jet strength and the radiative forcing due to stratospheric ozone changes.

Hereafter, we explain how we are able to improve the paper regarding the issues mentioned by the reviewer #1 in blue italic (actions taken on the manuscript are preceded by an arrow).

1. Section 2: The used model setup is not clearly presented. I understand that FOAM+LPJ models are used to produce boundary conditions (topography, geography, 4xCO2 and so on) for Eocene. Then, in the section 2.2.2 it is said that CCM LR uses SST and land surface conditions. Does CCM LR use proper topography and land configuration?

The FOAM+LPJ model is prescribed with a 4x pCO_2 and an Eocene paleogeography to compute sea-surface temperatures, sea-ice extent and vegetation surface properties (albedo, roughness, landcover). We use these surface properties as boundary conditions for LMDz-REPROBUS (not CCM LR), together with the same Eocene paleogeograhy and greenhouse gas concentrations.

=> we have clarified the description of this set-up in the text and add a sketch describing the modelling set-up.

If the simulated period is around 55 Ma, why nothing is said about oxygen mixing ratio which was only about 17% and large increase of biogenic emissions (i.e., isoprene). These components can substantially change ozone mixing ratio in the both stratosphere and troposphere.

Oxygen variations are poorly constrained over such timescales. There is no consensus on the oxygen variations through the Cenozoic (see Fig 1 of Wade et al. 2018 presenting the different oxygen content reconstructions in the Phanerozoic and discussing the methodologies used to produce them in their introduction https://www.clim-past-discuss.net/cp-2018-149/cp-2018-149.pdf). In view of these uncertainties, the climate models use a present-day oxygen content to investigate past climates except studies specifically investigating the potential role of oxygen variations but in this case they focus on more ancient periods for which the estimations of large oxygen variations are in better agreement (e.g. Wade et al. 2018, Charnay et al. 2013).

Ref:

Wade, D. C., Abraham, N. L., Farnsworth, A., Valdes, P. J., Bragg, F., and Archibald, A. T.: Simulating the Climate Response to Atmospheric Oxygen Variability in the Phanerozoic, Clim. Past Discuss., https://doi.org/10.5194/cp-2018-149, in review, 2018.

Charnay, B., Forget, F., Wordsworth, R., Leconte, J., Millour, E., Codron, F., and Spiga, A.: Exploring the faint young Sun problem and the possible climates of the Archean Earth with a 3-D GCM, Journal of Geophysical Research: Atmospheres, 118, 10,414–10,431, https://doi.org/10.1002/jgrd.50808, 2013.

=> In the revised version, we now explain briefly the choice we made for oxygen content.

The suspected large increase in biogenic VOC (due to warmer climate) is of major concern for tropospheric chemistry but BVOC do not reach the stratosphere in significant amounts, being very quickly oxidized in the troposphere. However, they can impact the methane concentrations by altering the tropospheric oxidizing capacity as found by Beerling et al. [2011]. That's why we use, in our simulations, the CH_4 concentrations calculated by Beerling et al. [2011] who studied the tropospheric chemistry under Eocene conditions using a land-tropospheric chemistry-climate model.

How successful is FOAM simulations of the past climate? As far as I know the Eocene climate with no substantial horizontal temperature gradients is difficult to reproduce.

FOAM alone has been used specifically for the Eocene period in previous published studies (e.g., Zhang et al., 2012). In addition, numerous recently published paleoclimate studies are based on the two-step methodology based on FOAM and LMDZ and this set-up has been shown to perform well [e.g. Botsyun et al. 2019, Ladant et al., 2014; Ladant et al. 2016; Licht et al., 2014; Pohl et al. 2016; Porada et al. 2016].

Moreover, even if climate models, including FOAM, exhibit weaknesses in simulating past climates, this does not prevent exploring middle atmospheric ozone dynamic for paleo-climate modelling, in particular, under warm climates. One has to keep in mind that the main objective of the paper is to study stratospheric ozone changes, which have been neglected so far, under Eocene conditions and their potential importance for climate.

=> We now provide more information and references for LMDz-FOAM in the set-up section.

Ref:

Botsyun S., P. Sepulchre, Y. Donnadieu, C. Risi, A. Licht, J. K. Caves Rugenstein. "Revised paleoaltimetry data show low Tibetan plateau elevation during the Eocene.", Science (2019), *in press*.

Ladant, J. B., Y. Donnadieu, V. Lefebvre, and C. Dumas (2014), The respective role of atmospheric carbon dioxide and orbital parameters on ice sheet evolution at the Eocene-Oligocene transition, Paleoceanography, 29, 810–823, doi:10.1002/2013PA002593.

Ladant, J.-B. & Donnadieu, Y. Palaeogeographic regulation of glacial events during the Cretaceous supergreenhouse. Nat. Commun. 7:12771, doi: 10.1038/ncomms12771 (2016).

Licht, A., et al. (2014), Asian monsoons in a late Eocene greenhouse world, Nature, 513(7519), 501–506.

Pohl, A., Y. Donnadieu, G. Le Hir ,J.-B. Ladant, C. Dumas, J. Alvarez-Solas, and T. R. A. Vandenbroucke (2016), Glacial onset predated Late Ordovician climate cooling,Paleoceanography,31, 800–821,doi:10.1002/2016PA002928.

Porada, P. et al. High potential for weathering and climate effects of non-vascular vegetation in the Late Ordovician. Nat. Commun. 7:12113 doi: 10.1038/ncomms12113 (2016).

Z Zhang, F Flatøy, H Wang, I Bethke, M Bentsen, Z Guo, Early Eocene Asian climate dominated by desert and steppe with limited monsoons, Journal of Asian Earth Sciences, Volume 44, 2012, https://doi.org/10.1016/j.jseaes.2011.05.013.

From the first paragraph on page 6 I understood that CH4 and N2O have not been included in the CCM LR radiation code, but their influence is implicitly included in CO2. How exactly it was done? Did the author use greenhouse warming potential or some other scaling technique? I suggest rewriting section 2.2 to make it more understandable.

We agree that this point was not well explained.

Even if inferred from proxies, the temperature changes for Eocene are better known than the greenhouse gases content (for which only CO_2 level can be inferred but with large uncertainties). For this reason, paleoclimate modellers have investigated the Eocene climate running simulations with various CO_2 covering a large range of concentrations with the aim of reproducing the amplitude of surface temperature changes. They do not change the level of other GHGs because no data are available on them. However, as only CO_2 is adjusted to match the temperature difference it means that the CO_2 perturbation implicitly represents the sum of all the GHG perturbations. This methodology is the one recommended by Lunt et al. 2017 for the DeepMIP project. For that reason we only perturb CO_2 in FOAM and LMDz for Eocene simulations.

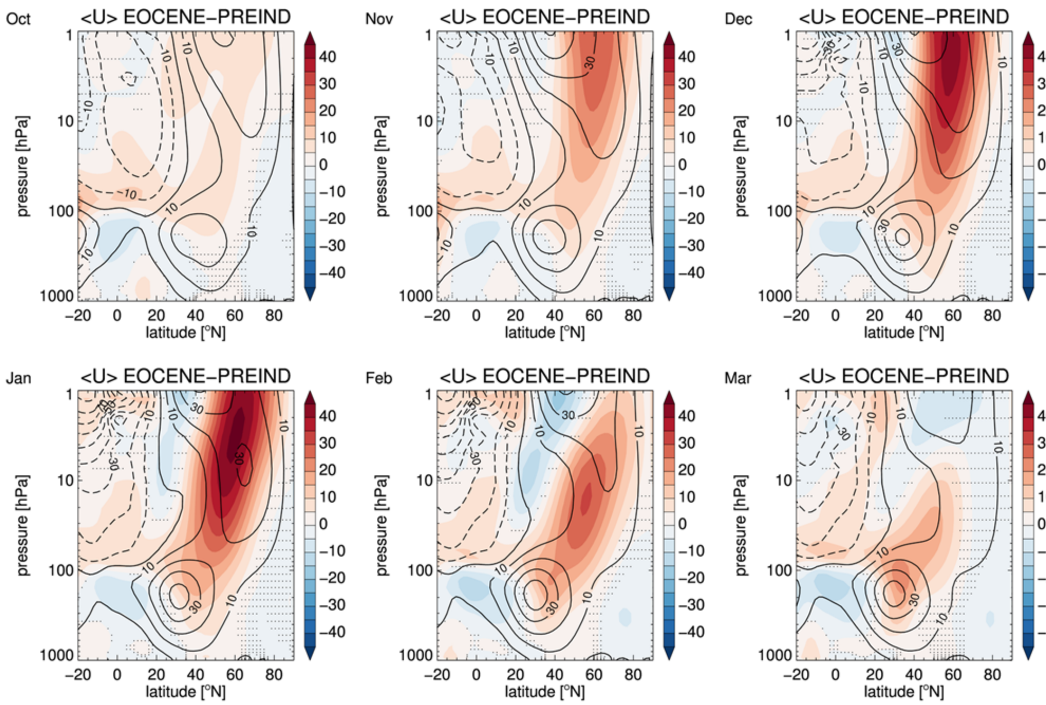
Thus, in the LMDz-REPROBUS chemistry-climate modelling, fixed CO_2, CH_4 and N_2O are used as inputs to the radiative scheme. As a result, only ozone changes influence the climate during a preindustrial or Eocene simulation. That way, the effect of ozone changes on middle atmospheric climate can be isolated and quantified. Obviously, ozone chemistry is also affected by changes in N_2O and CH_4, two key stratospheric source gases. To account for this effect, there are CH_4 and N_2O chemically active tracers (i.e. modified by the transport and chemistry schemes) and whose surface concentrations are taken from the modelling study of Beerling et al. 2011. Their global distributions change with time during a simulation, but they are not used as inputs to the radiative scheme and hence their changes do not affect the climate, only ozone changes do.

=> we have now clarified this point in section 2. 2 and in the Table 1

2. Section 3: Most of the results of this section agree well with several previous publications. On unexpected results is strong acceleration of the boreal polar night jet, which is more than two times stronger during Eocene. The authors explain it by the extra cooling of polar cap area by enhanced CO2. This result does not agree with previous publications. For example, for 4xCO2 case the acceleration of zonal wind was not detected (e.g., Ferraro et al., 2015, doi:10.1002/2014JD022734, Figure 4). Theoretically, it should be expected because the enhanced CO2 cools down stratosphere everywhere and does not build up additional horizontal gradients. Maybe the cause is not CO2? It should be clarified and analyzed.

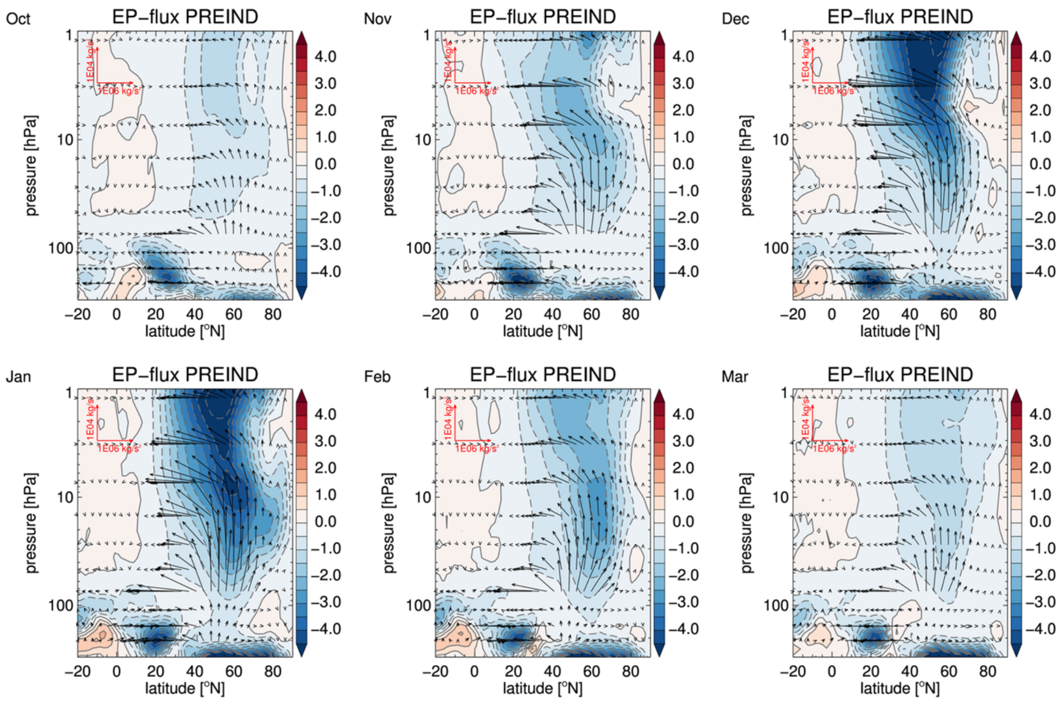
Indeed, the CO_2 cooling of the stratosphere should be uniform and hence would not affect the meridional temperature gradient. We thank the reviewer for noticing this flawed explanation, which is now removed from the revised version. This comment has prompted us into analyzing more thoroughly the mechanism. As shown on Figure 2b of the manuscript, however, the increase of ozone in the upper stratosphere could inflect further the shortwave heating rates gradient in the winter hemisphere. This is indeed what we found with an overall more negative meridional SW heating gradient throughout the depth of the stratosphere, which maximizes at the stratopause. This effect is however balanced by the fact that equatorial temperatures are decreasing at a faster rate than the polar temperatures in the Eocene simulation. So the net difference is slightly positive in the middle stratosphere and negative at the stratopause level. Radiative effects on the polar vortex in early winter due to CO_2 increase appear hence to be very modest compared to the changes in the wave activity as we describe further in the following.

As shown on Rev1 Figure 1 below, a much stronger stratospheric polar vortex develops in early winter (Nov-December) under the Eocene conditions compared to pre-industrial conditions. The strength of the polar night jet is doubled over the full depth of the stratosphere. By late winter (starting in January), the anomalies progressively reverse from the upper part of the stratosphere. In March, the stronger polar vortex anomalies in the middle atmosphere are no longer significant. To understand better such a seasonal evolution of the polar vortex, we have performed some transformed eulerian mean calculations [*Andrews et al*., 1987] in order to diagnose the resolved wave activity changes and their interaction with the mean flow. We first examine the climatology of the EP-flux and its divergence in the preindustrial experiment and then analyse the anomalies when moving to Eocene conditions.



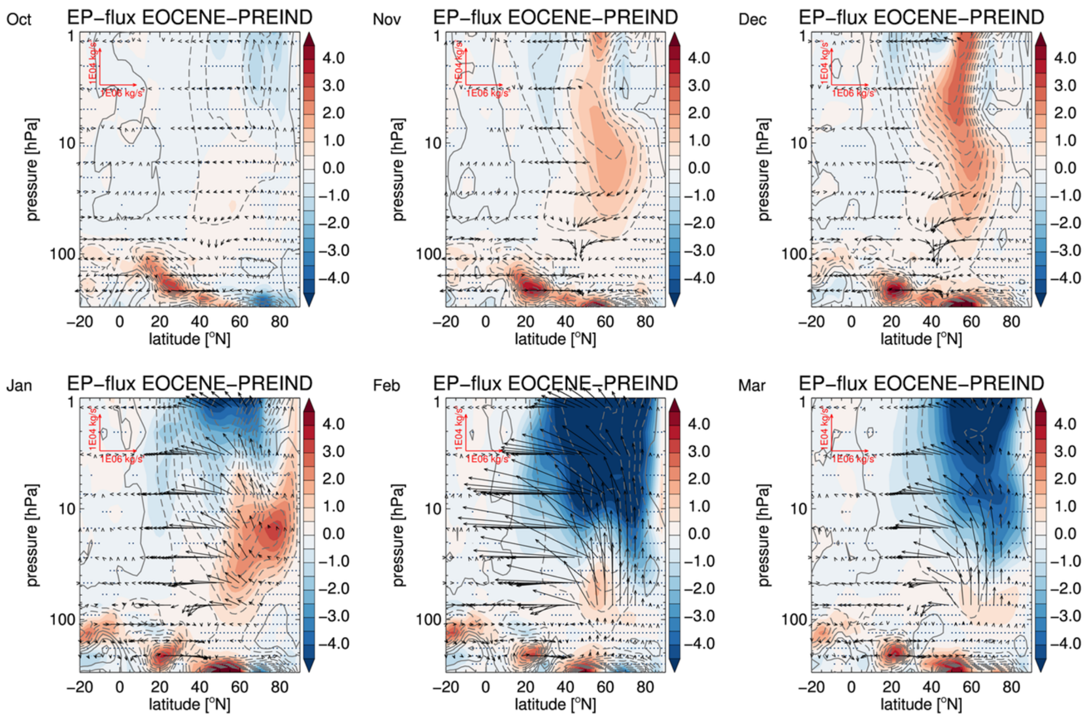
Rev1 Figure 1. Seasonal evolution (Oct to Mar) of the zonal mean zonal wind differences between the Eocene and preindustrial conditions. Shaded contours indicate that anomalies are significant at the 5% levels according to a t-test. Black contours show the preindustrial run climatology.

The preindustrial climatology of the planetary wave propagation (EP-flux) and its interaction with the mean flow (EP-Flux divergence) shows that, permanently in winter, the wave activity penetrates in the stratosphere and the breaking of planetary waves leads to westward momentum forcing which maximizes near the location of the southern flank of the polar night jet (Rev1 Figure 2). This contributes to erode and weaken the polar vortex, to a warming of the polar stratosphere and lead to a net poleward residual mass transport (which contributes the Brewer-Dobson circulation to a large extent). The wave activity and its interaction with the mean flow peaks in December-January but is already large in November (which can eventually lead to SSW [e.g. de la Camara et al., 2016]).



Rev1 Figure 2. Seasonal evolution (Oct to Mar) of the Eliassen-Palm Flux (vectors) and its divergence (contours, in m/s/d) under preindustrial conditions.

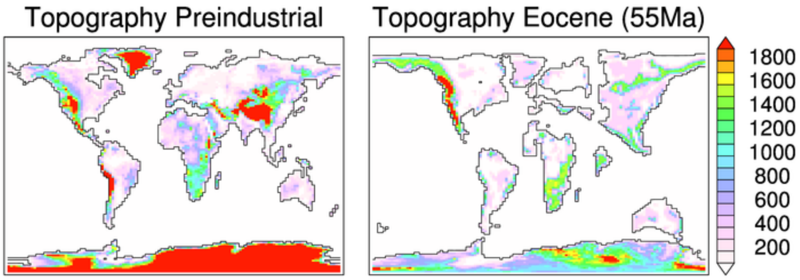
Under Eocene conditions (Rev1 Figure 3), it appears that the planetary wave penetrating the stratosphere in early winter (Nov-Dec) is significantly reduced and deflected equatorward as revealed by the EP-Flux vector pointing downward and equatorward in the mid-latitude lower stratosphere (see also Figure 7b showing a lower eddy heat flux at 100 hPa in the former version of the manuscript). This is associated with an anomalous positive E-P flux divergence throughout the depth of the stratospheric polar night jet (near 60°N), which indicates a reduced westward momentum forcing by waves and hence allows a stronger development of the polar vortex in early winter. In contrast, by January, the wave activity becomes significantly larger (see also Figure 7b), the westward forcing appears strongly amplified in the upper stratosphere and this momentum forcing anomaly progressively propagates downward. This is consistent with the reversal of the zonal-mean zonal wind anomaly in the upper stratosphere, but also with the overall extremely rapid deceleration of the polar vortex strength seen on Figure 6 of the former version of the manuscript. Relatively, the Brewer-Dobson circulation will hence be less reduced in early winter than accelerated in late winter (where the differences in the wave forcing are much stronger), resulting in a net acceleration of the Brewer-Dobson under Eocene conditions compared to preindustrial conditions as revealed by the younger age of air. Note that we also examined the residual circulation velocities v* and w* which confirms the seasonal changes in the Brewer-Dobson circulation strength (not shown).



Rev1 Figure 3. Seasonal evolution (Oct to Mar) of the differences between the Eocene and preindustrial conditions of the Eliassen-Palm Flux and its divergence. Shaded contours indicate that anomalies are significant at the 5% levels according to a t-test. Preindustrial climatology is shown with dashed contours.

The subsequent question is what causes these seasonal changes in the wave activity and its forcing on the mean flow. Potential factors that may play a role in modulating the wave activity are for instance SST changes (e.g. Hu et al., 2014), sea-ice changes (e.g. Kim et al., 2014), tropospheric wind changes (e.g. Karpechko and Manzini, 2017), and topography (Shi et al., 2014). However, to better quantify the relative importance of the above-mentioned various factors, a thorough detection/attribution experimental protocol would be needed. Such a detection/attribution study goes beyond the scope of our study whose aim is to characterize the stratospheric background state under Eocene-like extreme climate conditions. Nonetheless, we could analyze additional Eocene and Preindustrial experiments that have been performed with the same atmospheric model (LMDz) but without interactive chemistry (i.e. preindustrial ozone is prescribed) and with a flat topography. It appeared very clearly that changes in the topography have first order effects on wave development and propagation and hence on the stratospheric polar vortex. Between the Eocene and the preindustrial eras, beside large changes in the topography (see Figure below), changes in air-sea thermal contrasts, sea-ice cover, sea surface temperature, can all have a substantial effect on the background state atmospheric circulation, wave activity and hence the stratosphere dynamics. The complexness of these effects and their possible interactions make an unambiguous attribution impossible in the absence of a devoted experimental protocol that is out of reach for the present study.

=> In the revised version of the manuscript, the seasonal stratosphere dynamics analysis shown above is now the section 3.2, which has been renamed “Seasonal evolution of the Northern Hemisphere stratospheric polar vortex in Eocene conditions”. Figures 5 and 6 have been removed and replaced by the three Figures shown above. Figure 5 has been moved in the supplementary material as we believe that it illustrates very clearly the seasonal changes of the polar vortex. Topographic changes shown below have also been added in the supplementary material.



Rev1 Figure 4. Topography (in m) for (left) preindustrial and (right) early Eocene (-55 Ma) periods used as LMDz boundary conditions.

Ref

de la Cámara, A., Lott, F., and Abalos, M.:Climatology of the middle atmosphere in LMDz: Impact of source-related parameterizations of gravity wave drag, J. Adv. Model. Earth Sys., 8, 1507– 1525, https://doi.org/10.1002/2016MS000753, 2016.

Hu, D. Z., W. S. Tian, F. Xie, J. C. Shu, and S. Dhomse, 2014: Effects of meridional sea surface temperature changes on stratospheric temperature and circulation. Adv. Atmos. Sci.,31(4), 888–900, doi: 10.1007/s00376-013-3152

Karpechko, A. Y., & Manzini, E. (2017). Arctic stratosphere dynamical response to global warming. Journal of Climate, 30(17), 7071–7086. https://doi.org/10.1175/JCLI-D-16-0781.1

Kim, B.M., S.W. Son, S.K. Min, J.H. Jeong, S.J. Kim, X. Zhang, T. Shim, and J.H. Yoon (2014), Weakening of the stratospheric polar vortex by Arctic sea-ice loss, Nat. Commun., 5, doi:10.1038/ncomms5646.

Shi, Z., Liu, X., Liu, Y., Sha, Y., Xu, T., 2014. Impact of Mongolian Plateau versus Tibetan Plateau on the westerly jet over North Pacific Ocean. Climate Dynamics 44 (11-12), 3067–3076. 7

I would also suggest shortening second paragraph on page 8. I guess, most of the readers know the basic atmospheric dynamics.

The paragraph is now removed from the revised version. Nonetheless, we opted to keep the paper as accessible as possible for the broad readership of Climate of the past which is not necessarily expert in stratosphere dynamics.

3. Section 4: First of all, the considered effects are not related to interactive chemistry but rather to the use of not appropriate ozone field. I guess, most of the differences discussed in this section disappear if the authors use the model w/o interactive chemistry, but with the ozone field prescribed from the Eocene run. I do not see any reason to compare Eocene run with the results of the model run driven by OzRoyer. Obviously, there will be substantial difference due to different situation during Eocene and present day. Comparison with Oz1855 is also not instructive because the ozone field is very close to the results of preindustrial run.

We agree that the problem is the ozone field, that is exactly the point the paper is trying to make! In many paleo-climate modelling studies, the ozone field is simply a pre-industrial climatology. Our results suggest that it is not appropriate for Eocene-like conditions and has implications for climate. Our comparisons of the different simulations illustrate the sensitivity of the model-calculated middle atmospheric climate to the ozone field for Eocene conditions. In a way, using a pre-industrial ozone climatology is neglecting ozone chemical and dynamical feedbacks. A better way for having a more realistic ozone for Eocene climate is to have interactive chemistry in climate model, allowing to calculate an ozone field consistent with the paleo-climate. It's true that using a proper ozone climatology (i.e. calculated for Eocene conditions and ideally being a multimodel mean) could partly solve the problem. We do not argue that online coupling is required. We know this can be very difficult due to the computational cost of atmospheric chemistry and chemical tracer transport. In the abstract and conclusion of the paper that we recommend the use of suited ozone climatologies but not necessary an interactive chemistry climate model.

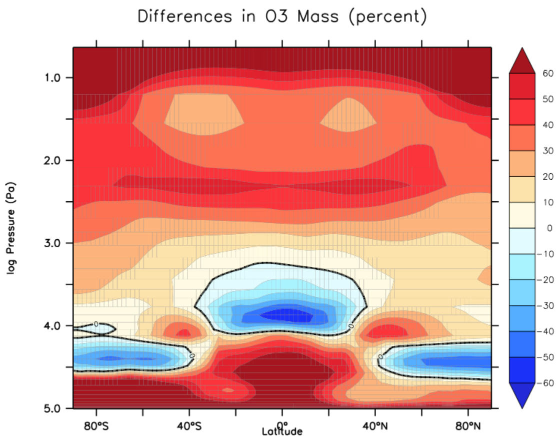
*4. Section 5: The problem here is related to the magnitude of radiative forcing. 1.8 W/m**2 from stratospheric ozone increase looks extremely overestimated and has probably wrong sign. Forster et al., 2011 (doi: 10.1029/2010JD015361) showed using very accurate LBL radiation codes that 10% decrease of the stratospheric ozone gives only about 0.25 W/m**2 (their Table 4). Portman and Solomon (2007, doi:10.1029/2006GL028252) concluded that the ozone radiative forcing caused by warming climate is within 0.1 W/m**2. I think that very large 1.8 W/m**2 ozone forcing (comparable to anthropogenic radiative forcing during 21st century) should be clearly explained. At least, its geographical, vertical and spectral signatures should be illustrated. In my opinion this forcing can be generated only by extraordinary high increase of the tropospheric or UTLS ozone (e.g., Beerling, 2011), which is not visible from presented results.*

In order to answer this comment and explain the 1.7W/m^2 radiative forcing (RF), we first explain briefly the set-up of the Forster et al., 2011 and Portman and Solomon (2007) studies and how our results are comparable (or not) with these studies. Then we discuss the climatic response in term of ozone RF and subsequent atmospheric changes in our set of simulations.

Portman and Solomon (2007) quantified the indirect effect of CO_2, CH_4, N_2O increases, via stratospheric ozone changes. They use for that 2 projections of GHG for 2100 (scenarios SRES A2 and B1). In these scenarios, the GHG increases are far lower than the ones we consider. Based on these projections, they find radiative forcings due to ozone changes of -0.03 and +0.09 W/m**2 depending on the scenario (their Table 2). It means that the sign of the RF due to stratospheric ozone change induced by simultaneous increase of several GHG is not obvious because the effect of CO_2 competes with the effect of CH_4 and N_2O, in particular in the altitude of ozone change (see their figure 2, 3 and 4). Thus, based on this study, it is not possible to argue that the sign of RF is obvious under warmer climate.

Forster et al. 2011 assessed the effect of an uniform 10% stratospheric ozone depletion for pressures less than 150hPa and find a positive RF of 0.25 W/m**2 (resulting from a negative RF, -0.094 W/m**2, in the longwave and a positive, 0.34 W/m**2, in the shortwave). Bekki et al. 2013 used the same radiative model and also found that the longwave and short wave RF are both strongly affected by stratospheric ozone changes: They show that the ozone depletion in the tropical lower atmosphere leads to a positive forcing in the tropics due to a dominant positive RF in the short wave. However, based on multi-model climatologies from the future projections of CCMVal-2 exercises, Bekki et al. 2013 have also shown that this positive RF due to the depletion of ozone in the lower tropical stratosphere compete, in the tropics, with the negative RF due to ozone increase in the upper stratosphere when considering future climate and GHG conditions (see their Figure 2). Considering both lower and upper stratosphere, the RF is then negative in the tropics. In addition the ozone response to GHG and climate changes (and its subsequent RF) are of opposite signs in the tropics and extratropics (see their Figure 2) resulting finally in a positive multi-model mean RF of +0.131 W/m**2 whereas RF for individual model projections lie in the -0.001 to +0.268 W/m**2 interval. Therefore, it is not possible to assess the sign and amplitude of RF from stratospheric ozone changes without the use of a radiative model because of the extreme sensitivity of ozone RF to the altitude and latitude of ozone changes and the resulting competing effects in the SW and LW. This point is also highlighted by Bekki et al. 2013 (see their section [10]) who found a poor correlation between the global mean stratospheric ozone change and the RF.

Rev1 Figure 5 hereafter presents the distribution of ozone changes in order to facilitate comparisons with those discussed in Figure 2a of Bekki et al. 2013. In Bekki et al. 2013, the changes of ozone mass (between 2000 and 2100) reaches +40% for large part of the stratosphere, with maximum increase in the upper stratosphere and extra-tropical lowermost stratosphere. In the tropical lower stratosphere, the ozone decrease peaks at 20%. Under Eocene conditions, we calculate here ozone increases in the upper stratosphere exceeding 40% and reaching up to 60-70%. The depletion of tropical ozone in the lower stratosphere is also much higher, exceeding 60%. In addition, the structure of the ozone changes differs from Bekki et al. ozone changes with an ozone decrease in the polar UTLS but a substantial increase in the tropical troposphere and subtropical barrier region. Our ozone changes are also, in magnitude, well beyond those presented in Figures 2 to 4 of Portman and Solomon (2007) which culminate in a 30% increase at 40km as a consequence of CO_2 increase for all the latitudinal band and an 8% decrease at about 24km for tropical latitudes. The differences in latitudinal mean profile in our simulation reach -50% for the 15°N and 15°S bands in the lower stratosphere and for the 75°N and 75°S bands in the upper troposphere. The ozone increase in the lower stratosphere at 45°N and 45°S reaches 40%. To conclude, the amplitude of the radiative forcing found in this study is greater than those reported in the publications mentioned by the reviewer since ozone changes are generally much higher and also differ in structure. As discussed in section 3.1, such large stratospheric ozone changes are not surprising for such a hot climate if we compare with studies on 4xCO2 climate.



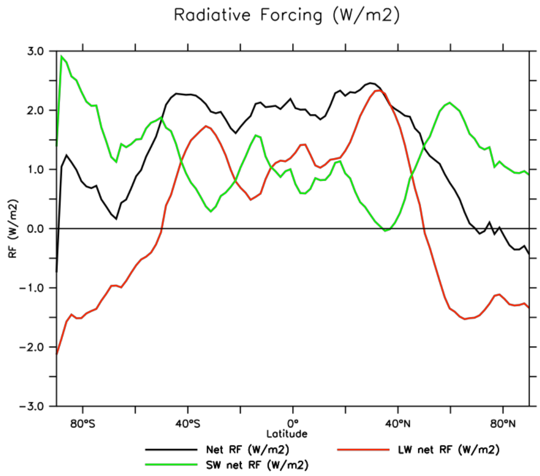
Rev1 Figure 5. Difference in O3 mixing ratio (%) between the Eocene Interactive O3 simulation vs the Eocene simulation using a 11 year mean climatology centered on 1855 (EOCENE- EOCENE_Oz1855).

The underlying changes in the SW and LW radiative forcing as a function of latitude are presented hereafter and are now added in the new version of the paper. For the tropics, RF is found to positive in both longwave and shortwave. Beyond 50°, the positive SW RF is partly counterbalanced by negative longwave RF.

Net = 1.69 W.m^{-2}

	Downward		Upward	Net	Net SW+LW
Top of Atmosphere	Shortwave	0.00	-1.00	1.00	1.80
	Longwave		-0.80	0.80	
200hPa	Shortwave	-0.20	-0.73	0.53	1.94
	Longwave	-0.11	-1.30	1.19	
Surface	Shortwave	0.30			

Rev1 Table 1. Differences in radiative fluxes between the interactive stratospheric chemistry (EOCENE) and the simulations using a 1855 climatology (EOCENE-Oz1855)



Rev1 Figure 6. Differences in radiative fluxes as a function of latitude between the interactive stratospheric chemistry (EOCENE) and the simulations using a 1855 climatology (EOCENE-Oz1855)

Other methodological differences exist in the way we compute RF compared with Portman and Solomon (2007) and Forster et al. 2011. Here, we use the methodology explained p669 of the 5th WGI assessment report of the IPCC consisting on computing the difference of the net top radiative fluxes at TOA in two GCM simulations forced by sea surface temperatures. It means that we compute the ozone radiative forcing taking into account the fast tropospheric feedbacks (e.g. changes in temperature, clouds and humidity profiles). Therefore, our ozone RF includes some of its indirect effects whereas Portman and Solomon (2007), Forster et al. 2011 and Bekki et al. 2013 only discussed direct ozone RF. In addition, in Portman and Solomon (2007) and in Forster et al. 2011, 2-D ozone distributions (latitudinal means) are considered whereas we use 3-D distributions.

=> The Rev1 Table 3 and Rev1 Figure 6 are now presented in the paper

*The estimation of the surface temperature response using some other model sensitivity to homogeneous radiative forcing is oversimplified. If the obtained 1.8 W/m**2 is true (which I doubt) it will show the importance of the problem by itself.*

As our aim is to show the importance of stratospheric ozone changes under Eocene conditions and their potential relevance for climate. We just want to know whether its climate effect is negligible or might be significant or even important compared to the effects of other parameters discussed in the literature. Our aim, by estimating rather crudely the temperature change, is not to be quantitative but to have a first estimation since stratospheric ozone changes and associated impact on surface climate have not been explored so far for Eocene conditions. Such estimation, even crude, allows to conclude on the potential importance of considering stratospheric ozone change in comparison to the change in boundary conditions.